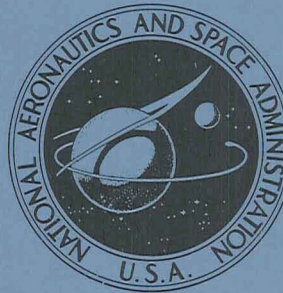


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COMPUTER-ACQUIRED PERFORMANCE  
DATA FROM A CHEMICALLY  
VAPOR-DEPOSITED-TUNGSTEN,  
NIOBIUM PLANAR DIODE

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16. Abstract  Performance data from a chemically vapor-deposited-tungsten, niobium thermionic converter are presented. The planar converter has a guard-ringed collector and a fixed spacing of 10 mils (0.254 mm). The data were acquired using a computer and are available on microfiche as individual or composite parametric J, V curves. The parameters are the temperatures of the emitter $T_E$ , collector $T_C$ , and cesium reservoir $T_R$ . The composite plots have constant $T_E$ and varying $T_C$ or $T_R$ , or both. The envelope and composite plots having constant $T_E$ are presented. The diode was tested at increments between 1500 and 2000 K for the emitter, 746 and 1149 K for the collector, and 545 and 652 K for the reservoir. In all, 479 individual current, voltage curves were obtained.					
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# COMPUTER-ACQUIRED PERFORMANCE DATA FROM A CHEMICALLY VAPOR-DEPOSITED-TUNGSTEN, NIOBIUM PLANAR DIODE

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## SUMMARY

A fixed-spaced planar diode with a guarded collector has been performance mapped in a multistation facility which is connected to a centralized computer data acquisition system. The chemically vapor-deposited tungsten emitter was separated from the niobium collector by 10 mils (0.254 mm). The use of the computer system allowed off-design as well as design conditions to be observed. Temperatures ranged from 1500 to 2000 K for the emitter ( $T_E$ ), 746 to 1149 K for the collector ( $T_C$ ), and 545 to 652 K for the cesium reservoir ( $T_R$ ). The composite plots and their envelopes, with constant  $T_E$  and varying  $T_C$  and  $T_R$ , are presented. Each of the 479 current, voltage curves was obtained in approximately 10 milliseconds with a variable transistorized load controlled by the central digital computer.

## INTRODUCTION

More power at lower temperatures is the goal for nuclear thermionic diodes. Providing that improvement means intensive testing of the best existing emitters and collectors, promising new electrodes, and additives. To ensure success, performance mapping must cover off-design as well as optimum operating conditions - with special attention to stability problems. Part of this program is the evaluation of six planar diodes with guarded collectors of niobium or molybdenum spaced 1/4 millimeter from emitters of rhenium or tungsten (ref. 1). The results obtained for the electrode combination of a chemically vapor-deposited tungsten emitter and a niobium collector are reported here. Similar results for emitters of vapor-deposited tungsten and of etched rhenium with niobium collectors are presented in references 2 to 4.

Data were recorded using a computer system as described in reference 5. This facility allows the rapid application of a variable transistorized load and makes possible the testing at off-design as well as design conditions. The data are presented on composite J, V plots holding the emitter temperature ( $T_E$ ) constant and varying the collector and cesium reservoir temperatures ( $T_C$  and  $T_R$ ). Data were gathered between 1500 and 2000 K for the emitter, 746 and 1149 K for the collector, and 545 to 652 K for the reservoir.

## TEST FACILITY

### Test Stations

The converters (fig. 1) were fabricated, then filled with cesium by the contractor.<sup>1</sup> They may be mounted in any of six vacuum test facilities which have a central instrumentation control panel. Each station has its own set of emitter (electron-bombardment), collector, and cesium-reservoir heat supplies. Thermal balance of the collector and reservoir is achieved through conduction to water lines. Typical operating pressures under heat load for these systems are less than  $5 \times 10^{-7}$  torr after a thorough bake-out.

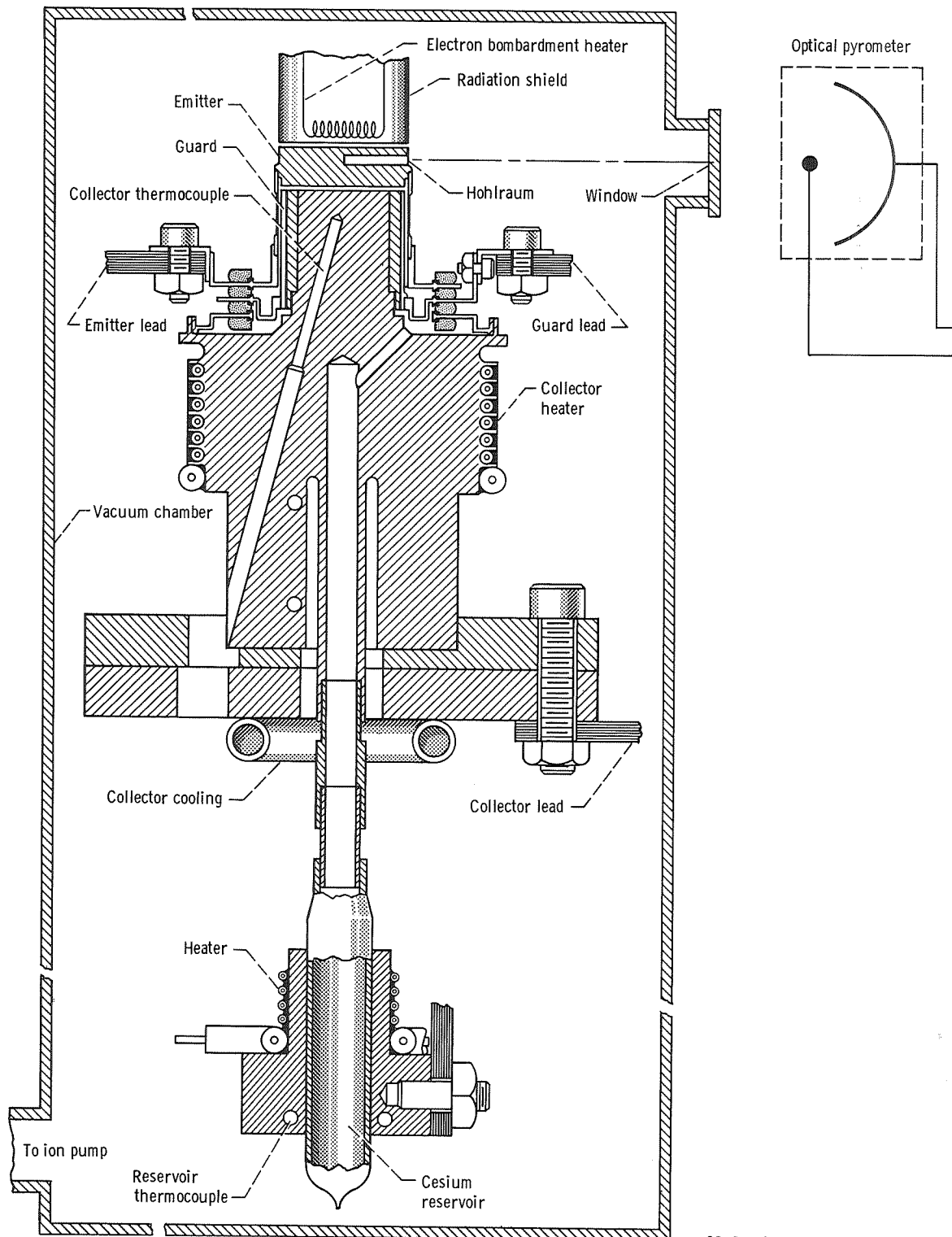
### Instrumentation

The current developed in the converter was measured by the voltage drop across either a 0.01- or 0.1-ohm precision shunt. The emitter, collector potential difference was measured at the external shroud of the converter. No corrections were made for the voltage drop in the emitter support shroud since it is approximately 1.8 millivolts per ampere per square centimeter of electrode surface. The current density was determined for the 1.55-square-centimeter collector. The guard ring was connected to the circuit on the opposite side of the shunt from the collector.

The collector and cesium reservoir temperatures were observed using sheathed Chromel, Alumel thermocouples embedded in their respective converter structures. The couples were continuous and were brought through the vacuum wall of the test station into a common ambient cold junction zone. The temperature of the ambient zone was sensed by a Chromel, Alumel couple that was referenced electronically to 273 K. Two couples were inserted at each location. The cesium reservoir couples were located in the copper block surrounding the copper tube containing the cesium (fig. 1). The collector couples were inserted to within 125 mils (3.05 mm) of the collector surface. The

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<sup>1</sup>Thermo Electron Engineering Corp., Waltham, Mass.



CD-10962-17

Figure 1. - Converter configuration.

standard Chromel, Alumel calibration for all four couples was verified by an in situ comparison against a reference Chromel, Alumel couple.

The emitter temperature was sensed by a sheathed high-temperature couple of tungsten, 5-percent-rhenium against tungsten, 26-percent-rhenium. The couple was inserted to a depth of 250 mils (6.35 mm) from the emitter substrate edge and 130 mils (3.3 mm) from the active face of the emitter (see fig. 1). Compensating lead wires were attached to the couple on the interior of the test chamber and were brought out to a room-temperature junction. The high-temperature couple was calibrated in place against a black-body cavity (length-to-diameter ratio of 5) in the emitter in the same plane of the thermocouple. Observations of the black-body cavity were made through a window in the test station with a disappearing filament optical pyrometer. The optical path and pyrometer were calibrated against a National Bureau of Standards (NBS) tungsten strip lamp. The maximum uncertainty associated with the observed temperature is approximately  $\pm 10$  degrees. This estimate takes into account the accuracy of the NBS calibration, the reversal capabilities of the optical pyrometer and observer, the effect of the approximate black-body cavity, and the goodness of fit of the linear calibration curve obtained for the couple. The temperature difference between the emitter thermocouple location and the active face of the tungsten emitter is considered negligible based on a one-dimensional heat balance of the radiation across the interelectrode gap and the heat conducted through the emitter. This model neglects any heat flow through the emitter-support shroud since the electron-bombardment filament was designed to nullify this heat path. Electron cooling effects on the surface temperature are negligible since the diode stands by with retarded current and the load is applied for a very short period (ref. 5). The contribution of gaseous conduction is negligible.

## TEST PROCEDURE

The computer-controlled data acquisition system is programmed (program developed by E. J. Manista and C. Kadow of NASA-Lewis) to trigger the variable load at up to six different emitter temperatures during a given test interval, which is usually approximately 20 seconds. This is accomplished by sensing the emitter temperature and, upon its reaching a predetermined value, triggering the load. The actual temperature levels at which the system is triggered are introduced into the program by the operator as independent input data. The data recording program, synchronized with the variable load, samples the J, V characteristics of the converter at each temperature level 90 times during the load application of approximately 10 milliseconds duration. Sample and hold amplifiers coordinate in time the collector current and collector, emitter potential difference.

The converter was mapped by fixing the temperatures of the cesium reservoir and

the collector and heating the emitter to the predetermined levels. With changes in the programmed trigger levels, the emitter was tested at 50 K increments between 1500 and 2000 K. The collector temperature was then changed, and the preceding procedure was repeated. Observations were made at 100 K collector increments between 746 and 1149 K. The cesium reservoir temperature was then changed, and the procedure was again repeated. Reservoir effects were established at 25 K increments between 545 and 652 K. At least one pulse of the variable transistorized load was made at each one of the reservoir-, collector-, emitter-temperature combinations. All temperatures were recorded at the end of each J,V sweep. Between runs these analog temperatures were converted by the computer to their values in degrees Kelvin, then printed out for use by the operator in setting conditions.

## DATA PRESENTATION

Since the local computer can store and recall only a limited number of successive sweeps, the data are transmitted to the Lewis Central Computing Center for storage on magnetic tape and for some engineering calculations. The data are sorted into groups of common emitter temperatures and are displayed in order of ascending  $T_E$  on microfilm output. Both J,V and P,V (power density) curves are displayed, with the J and P scales being determined by the maximum of each sweep. Two additional sorts are done by the Central Computer: The data are grouped by common emitter and collector temperatures and varying reservoir temperatures. And they are grouped by common emitter and reservoir temperatures and varying collector temperatures. The computer plots all the sorted J,V data on parametric composites and displays them on the microfilm output. These have scales of -0.5 to 2 volts and 0 to 30 amperes per square centimeter.

Table I lists the temperature conditions for the composite plots presented in figures 2 to 12. These figures show all J,V data obtained at emitter temperatures from 1500 to 2000 K. The envelope of the points of these figures represents the optimum performance of the converter for the range of operating conditions. All the envelopes for the different  $T_E$ 's appear in figure 13. Although the last figure yields all the information contained in figures 2 to 12, the individual computer-processed plots are presented to illustrate the density of data required to adequately establish the optimum envelope. These envelopes were derived directly from limited numbers of specific local J,V curves. As such, they lack the overall correlative influence of interpolation from the entire body of data. Their forms, therefore, will change somewhat in future refined interpretations.

In all, 479 individual J,V plots were generated in developing the envelopes. These are available in microfiche form on request. Also available on microfiche are J,V

composites at constant  $T_E$  and constant  $T_C$  or  $T_R$ . Table II lists the temperature conditions included on these computer-processed plots.

Lewis Research Center,  
National Aeronautics and Space Administration,  
Cleveland, Ohio, June 22, 1971,  
120-27.

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TABLE I. - TEMPERATURE CONDITIONS FOR COMPOSITE

PLOTS (FIGS. 2 TO 12)

Figure	Emitter temperature, $T_E$ , K	Collector temperature, $T_C$ , K	Cesium reservoir temperature, $T_R$ , K	Number of current, voltage curves
2	1500	749 to 1148	545 to 651	40
3	1550	748 to 1148	545 to 651	↓
4	1600	748 to 1148	545 to 651	
5	1650	749 to 1149	545 to 651	
6	1700	749 to 1148	545 to 651	
7	1750	746 to 1148	545 to 652	80
8	1800	746 to 1147	546 to 652	40
9	1850	746 to 1147	546 to 652	↓
10	1900	747 to 1147	546 to 652	
11	1950	747 to 1149	546 to 652	
12	2000	747 to 1148	546 to 652	39

TABLE II. - TEMPERATURE CONDITIONS FOR COMPUTER-PROCESSED PLOTS

Emitter temperature, $T_E$ , K	Collector temperature, $T_C$ , K	Cesium reservoir temperature, $T_R$ , K	Emitter temperature, $T_E$ , K	Collector temperature, $T_C$ , K	Cesium reservoir temperature, $T_R$ , K
1500	750	551 to 649	1800	750	551 to 649
	850	551 to 650		850	552 to 649
	900	550 to 651		900	553 to 650
	950	551 to 650		950	553 to 651
	1000	552 to 650		1000	552 to 650
	1050	550 to 651		1050	551 to 652
	1150	545 to 647		1150	546 to 647
1550	750	551 to 649	1850	750	551 to 649
	850	550 to 650		850	552 to 650
	900	550 to 651		900	553 to 650
	950	551 to 650		950	553 to 651
	1000	552 to 650		1000	552 to 651
	1050	550 to 651		1050	551 to 652
	1150	545 to 647		1150	546 to 647
1600	750	551 to 649	1900	750	551 to 650
	850	551 to 650		850	552 to 650
	900	550 to 651		900	553 to 650
	950	551 to 650		950	553 to 651
	1000	553 to 650		1000	552 to 651
	1050	550 to 651		1050	551 to 652
	1150	545 to 647		1150	546 to 647
1650	750	551 to 650	1950	750	551 to 650
	850	551 to 650		850	552 to 650
	900	550 to 651		900	553 to 650
	950	551 to 650		950	553 to 651
	1000	553 to 650		1000	553 to 650
	1050	550 to 651		1050	550 to 652
	1150	545 to 647		1150	546 to 647
1700	750	551 to 649	2000	750	551 to 650
	850	551 to 650		850	551 to 649
	900	550 to 651		900	552 to 650
	950	551 to 650		950	553 to 651
	1000	553 to 650		1000	552 to 650
	1050	550 to 651		1050	550 to 652
	1150	545 to 647		1150	546 to 646
1750	750	551 to 649			
	850	551 to 650			
	900	550 to 651			
	950	551 to 651			
	1000	552 to 650			
	1050	550 to 652			
	1150	545 to 647			

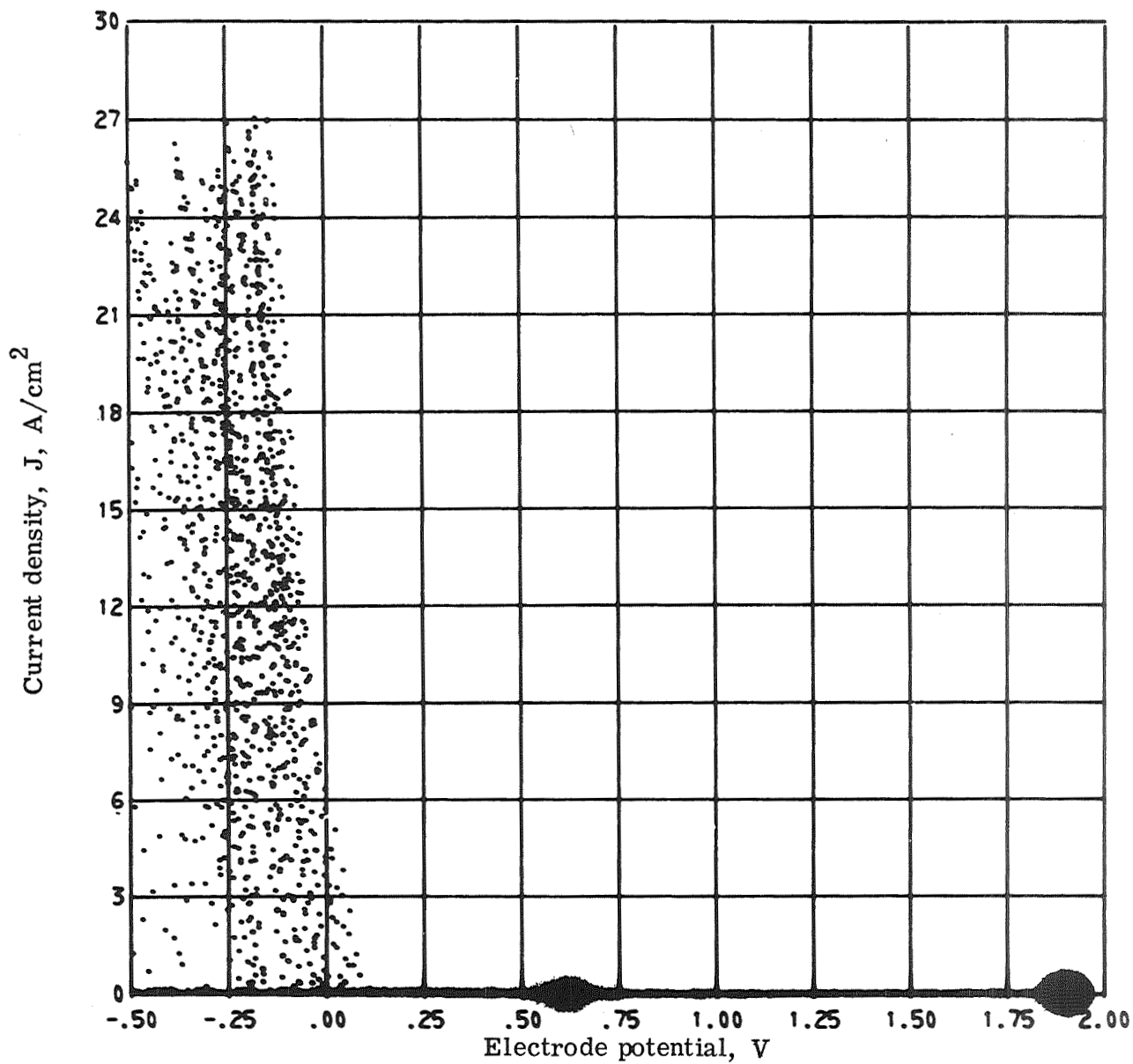


Figure 2. - Computer-processed composite of current, voltage data at constant emitter temperature of 1500 K. Collector temperature, 749 to 1148 K; cesium reservoir temperature, 545 to 651 K; interelectrode space, 0.254 mm (10 mils).

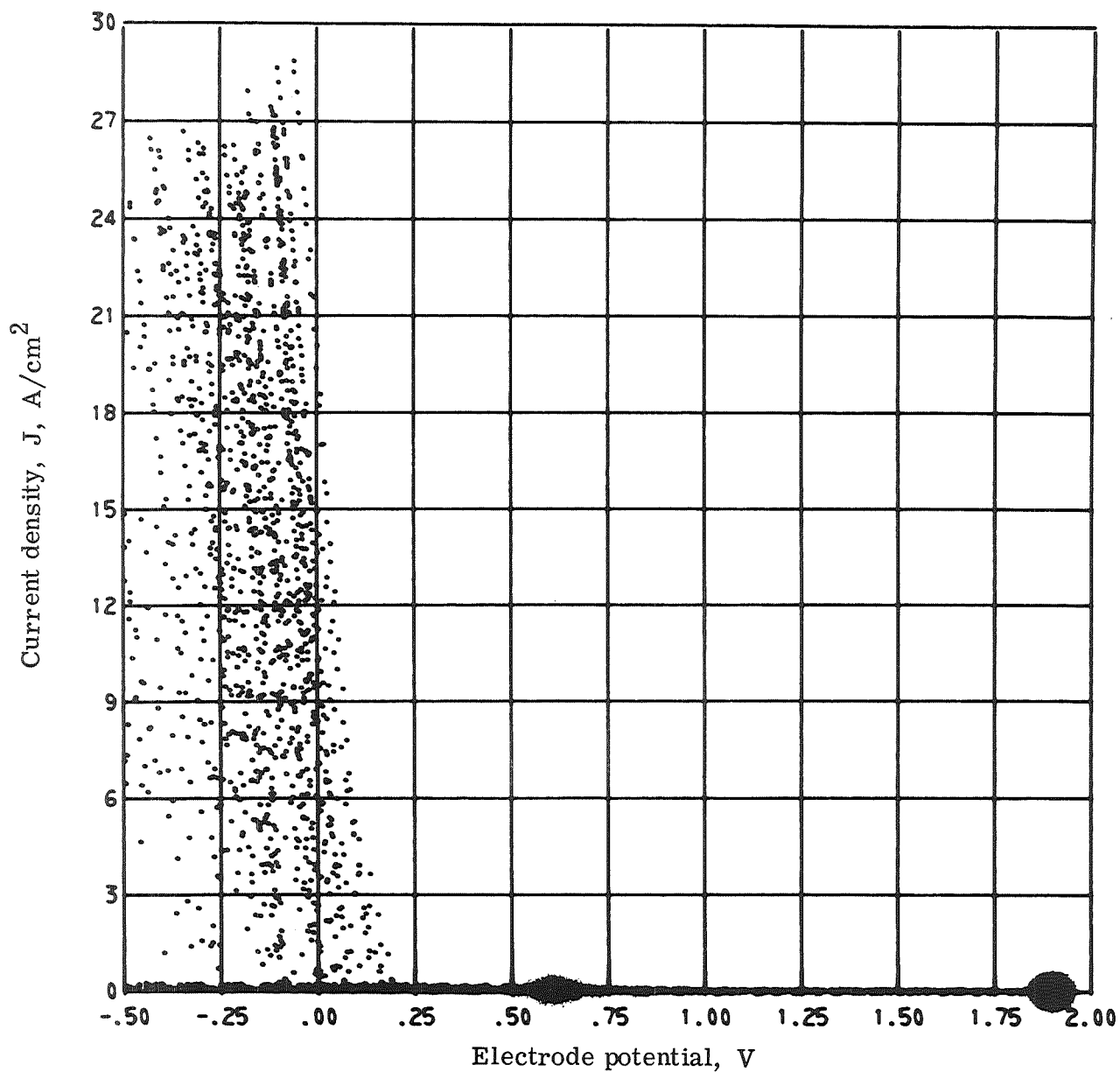


Figure 3. - Computer-processed composite of current, voltage data at constant emitter temperature of 1550 K. Collector temperature, 748 to 1148 K; cesium reservoir temperature, 545 to 651 K; interelectrode space, 0.254 mm (10 mils).

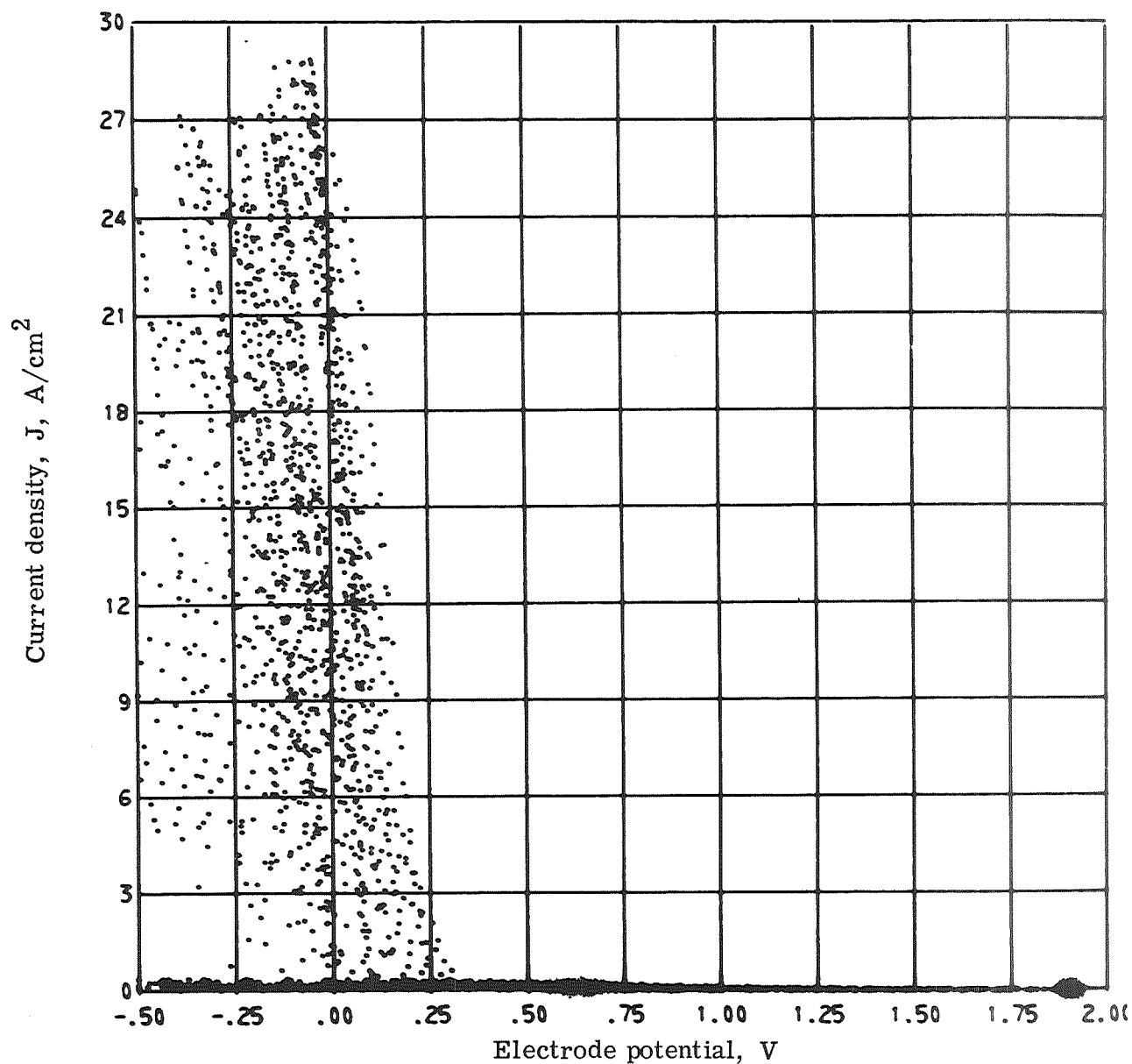


Figure 4. - Computer-processed composite of current, voltage data at constant emitter temperature of 1600 K. Collector temperature, 748 to 1148 K; cesium reservoir temperature, 545 to 651 K; interelectrode space, 0.254 mm (10 mils).

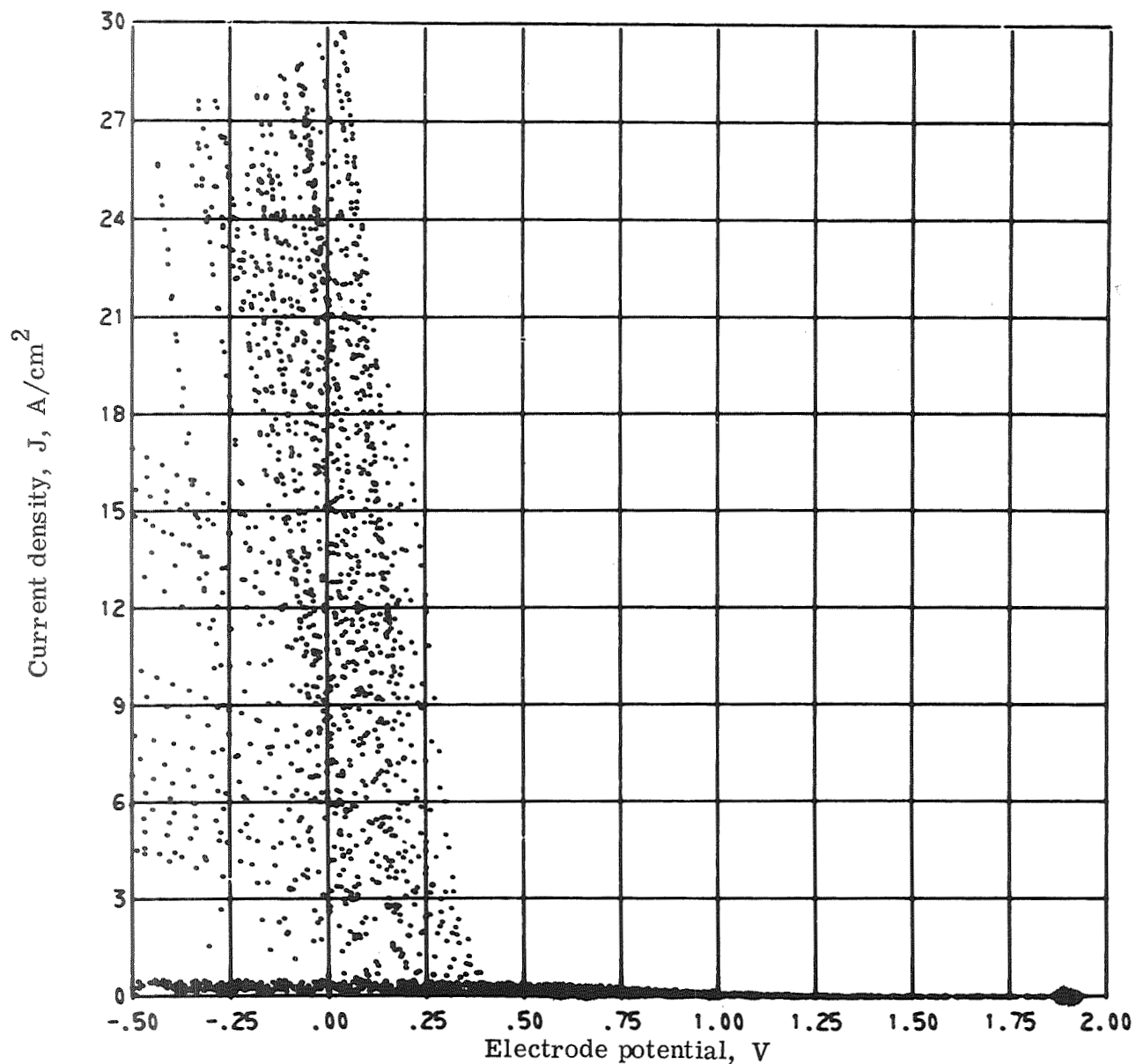


Figure 5. - Computer-processed composite of current, voltage data at constant emitter temperature of 1650 K. Collector temperature, 749 to 1149 K; cesium reservoir temperature, 545 to 651 K; interelectrode space, 0.254 mm (10 mils).

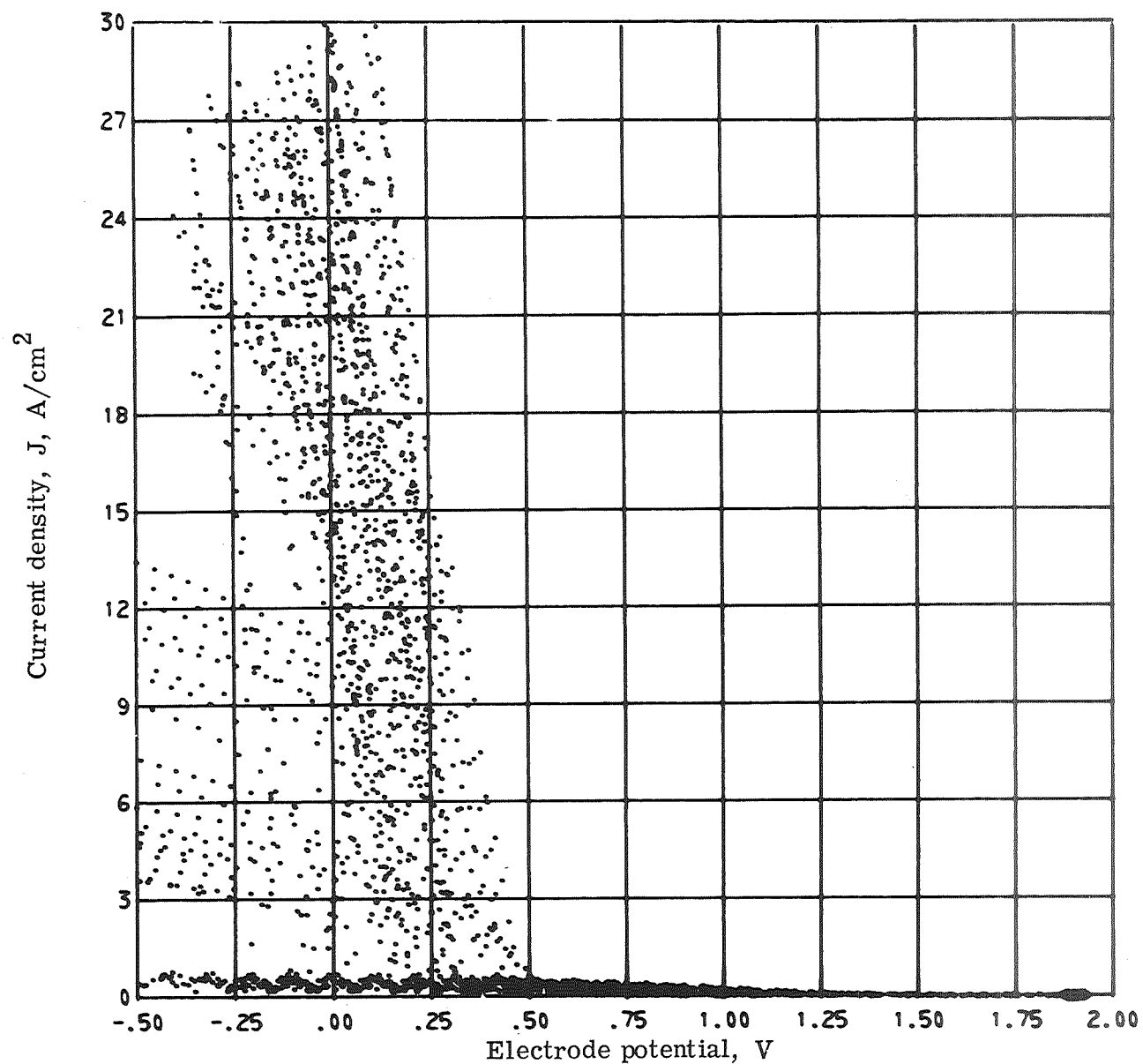


Figure 6. - Computer-processed composite of current, voltage data at constant emitter temperature of 1700 K. Collector temperature, 749 to 1148 K; cesium reservoir temperature, 545 to 651 K; interelectrode space, 0.254 mm (10 mils.)

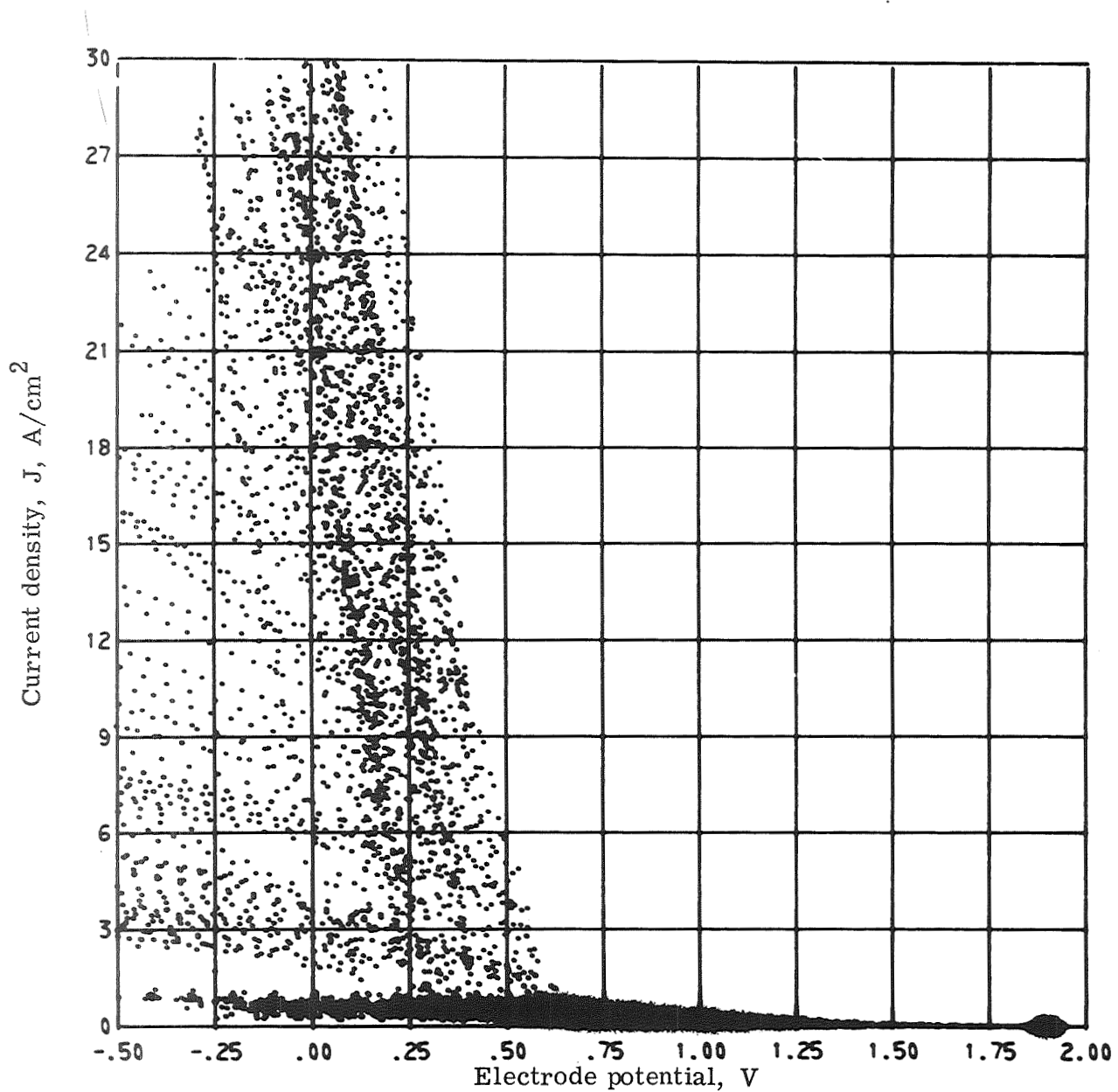


Figure 7. - Computer-processed composite of current, voltage data at constant emitter temperature of 1750 K. Collector temperature, 746 to 1148 K; cesium reservoir temperature, 545 to 652 K; interelectrode space, 0.254 mm (10 mils).

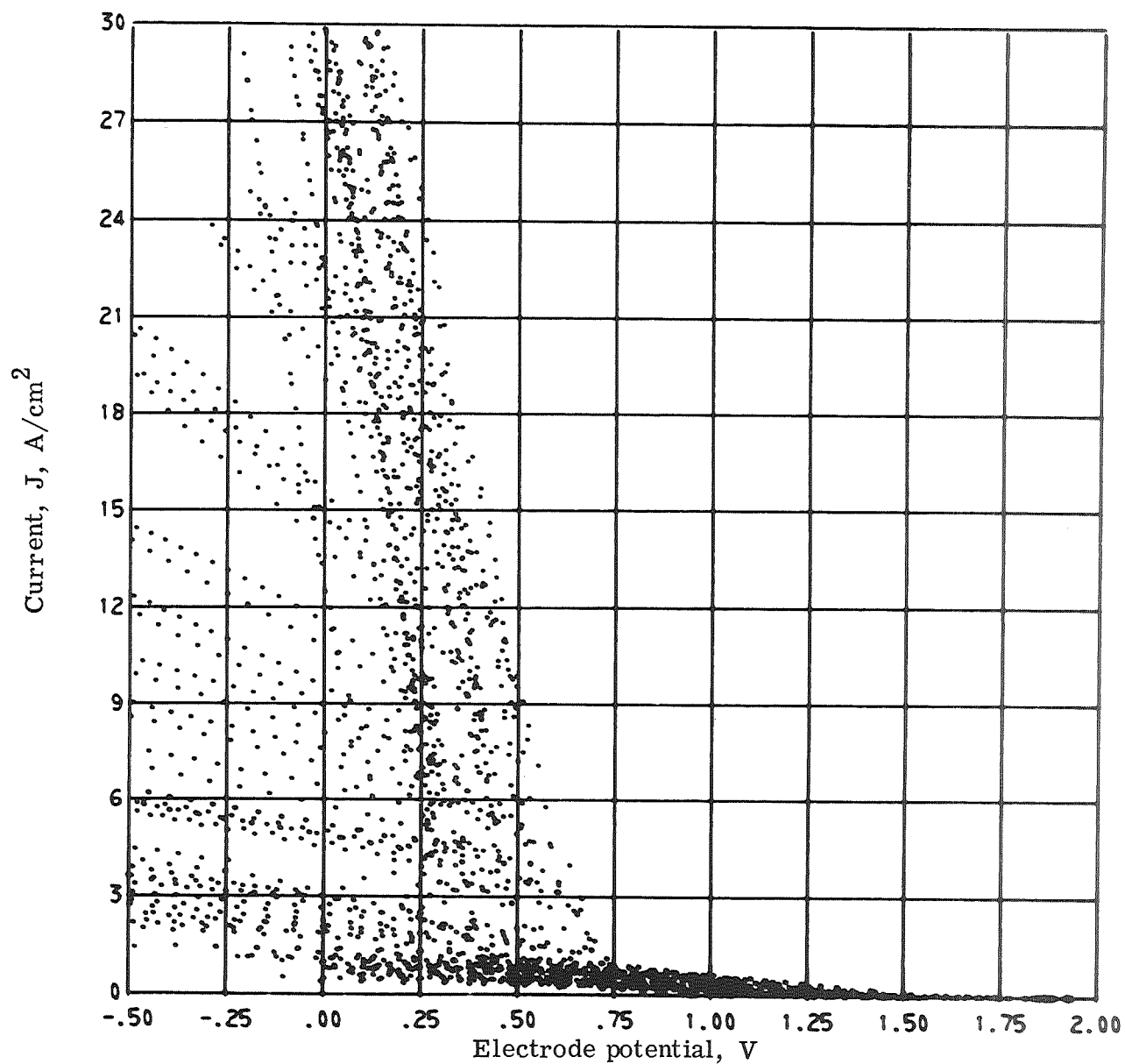


Figure 8. - Computer-processed composite of current, voltage data at constant emitter temperature of 1800 K. Collector temperature, 746 to 1147 K; cesium reservoir temperature, 546 to 652 K; interelectrode space, 0.254 mm (10 mils).

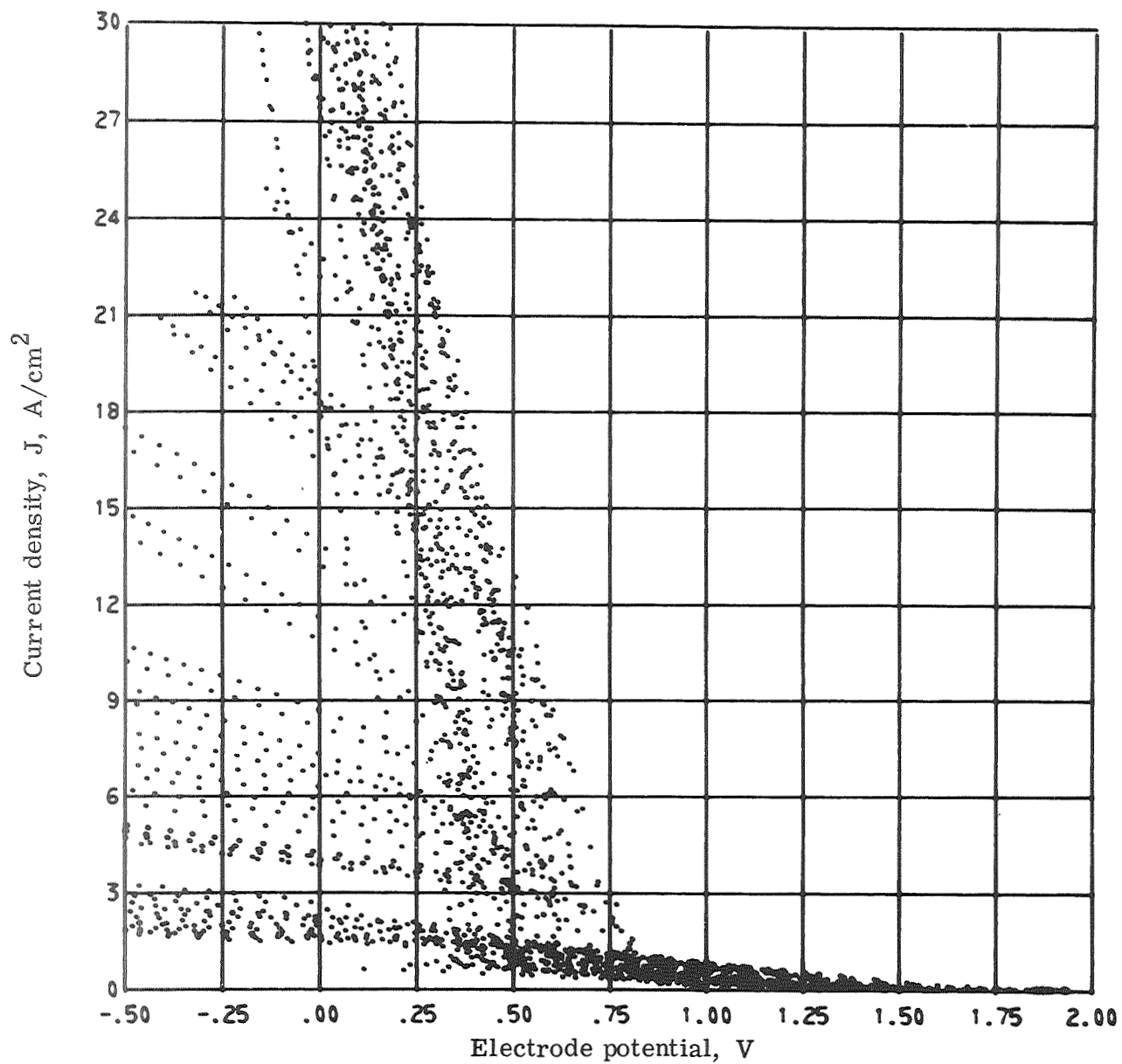


Figure 9. - Computer-processed composite of current, voltage data at constant emitter temperature of 1850 K. Collector temperature, 746 to 1147 K; cesium reservoir temperature, 546 to 652 K; interelectrode space, 0.254 mm (10 mils).

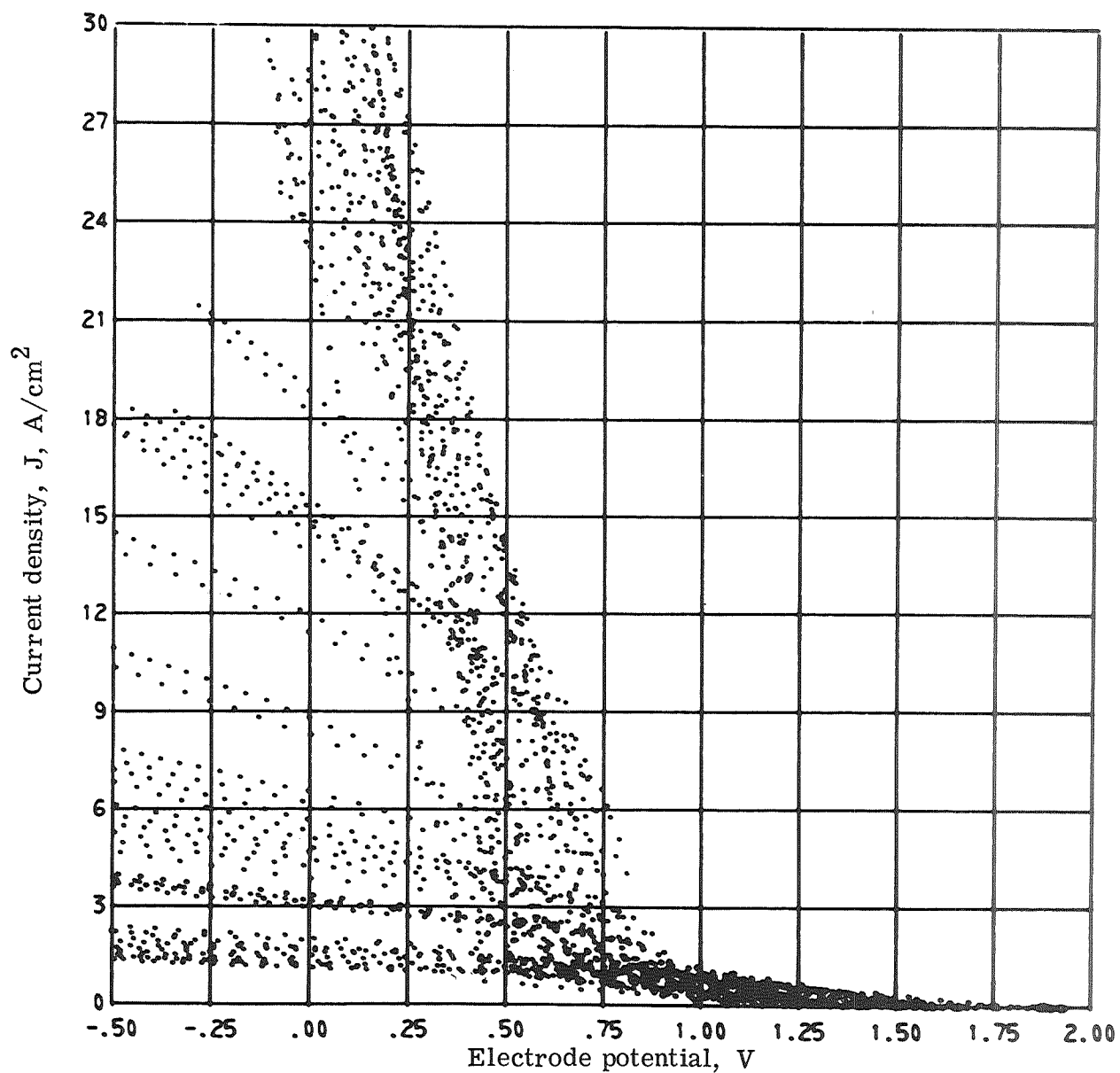


Figure 10. - Computer-processed composite of current, voltage data at constant emitter temperature of 1900 K. Collector temperature, 747 to 1147 K; cesium reservoir temperature, 546 to 652 K; interelectrode space, 0.254 mm (10 mils).

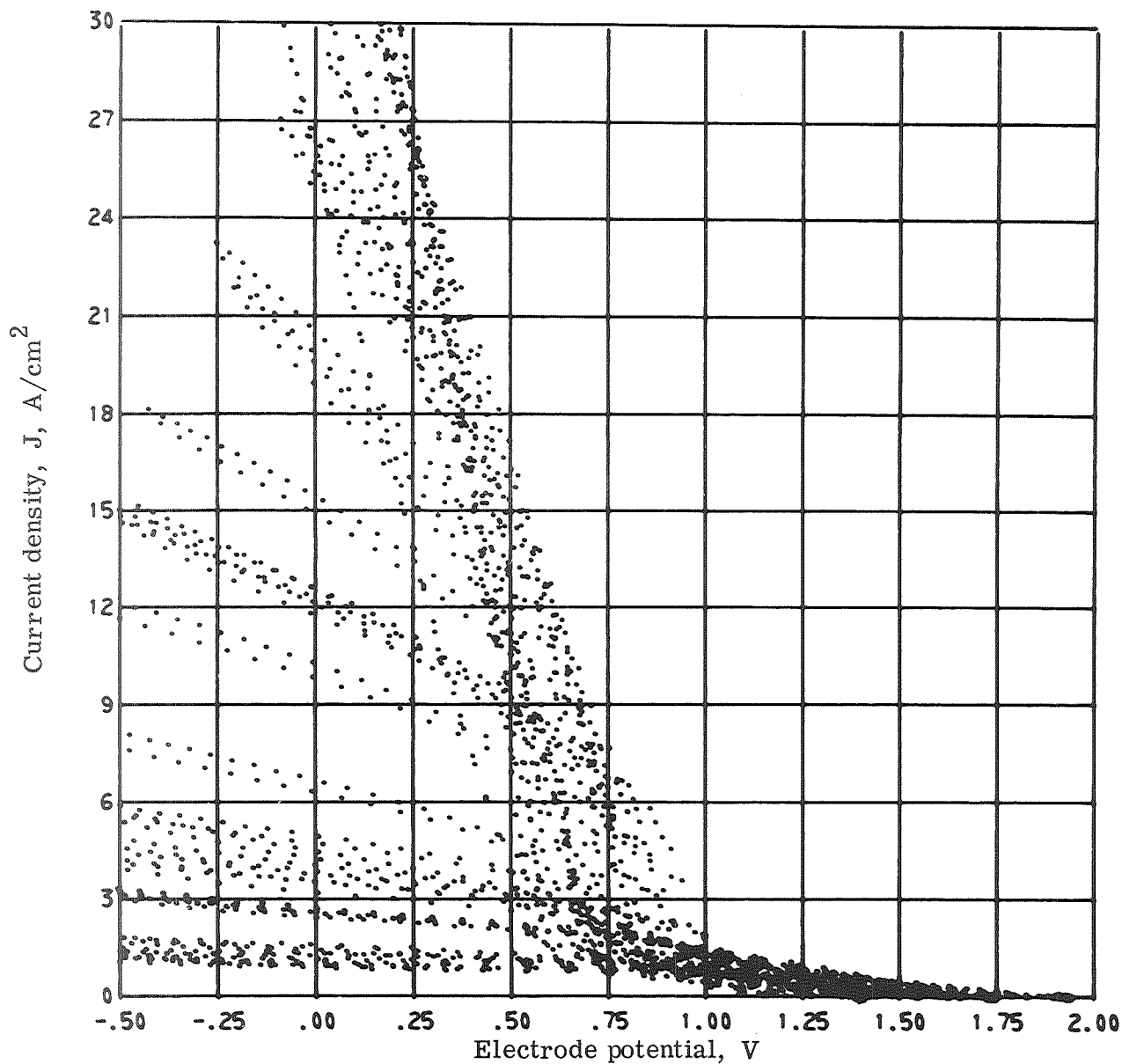


Figure 11. - Computer-processed composite of current, voltage data at constant emitter temperature of 1950 K. Collector temperature, 747 to 1149 K; cesium reservoir temperature, 546 to 652 K; interelectrode space, 0.254 mm (10 mils).

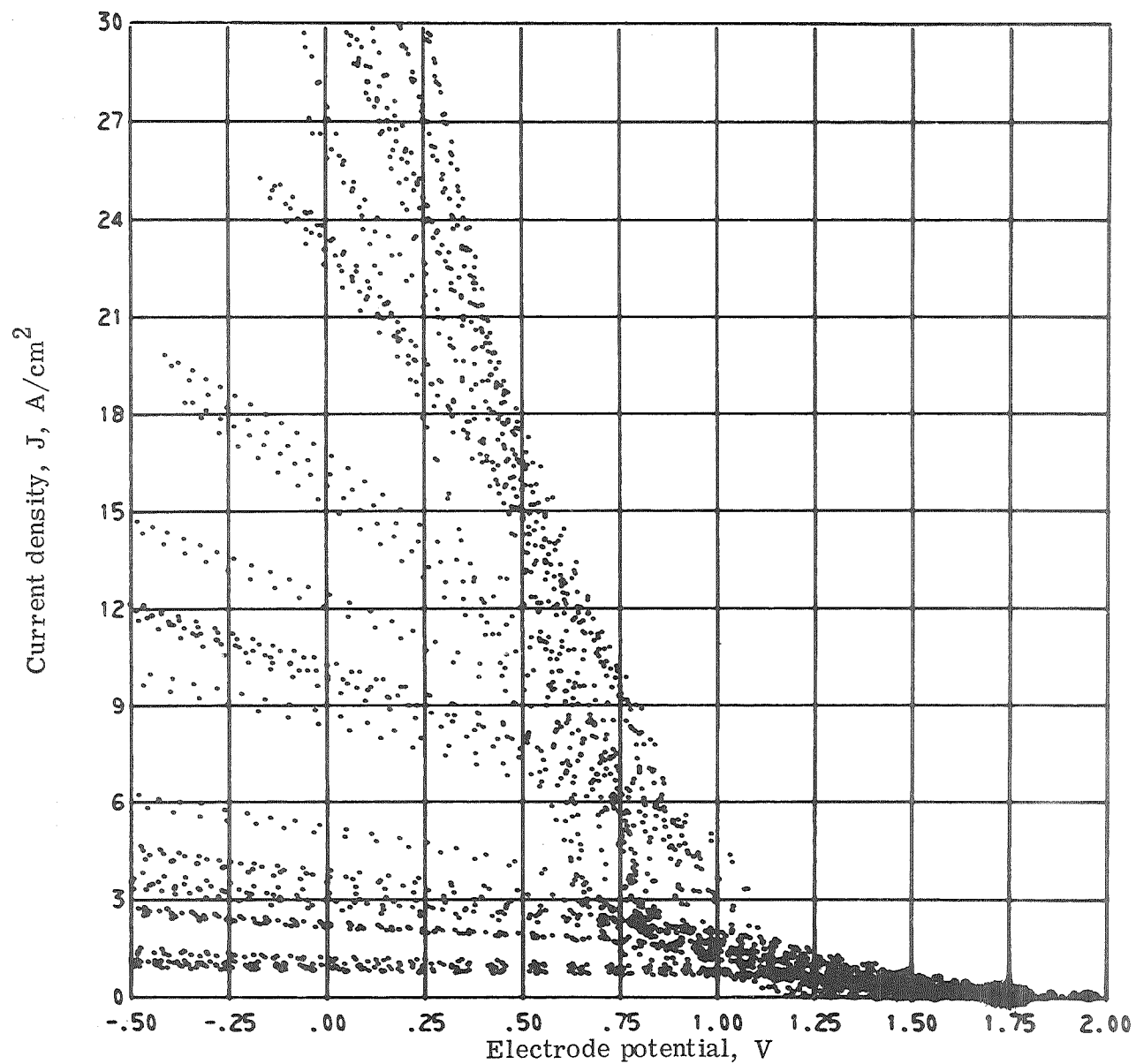


Figure 12. - Computer-processed composite of current, voltage data at constant emitter temperature of 2000 K. Collector temperature, 747 to 1148 K; cesium reservoir temperature, 546 to 652 K; interelectrode space, 0.254 mm (10 mils).

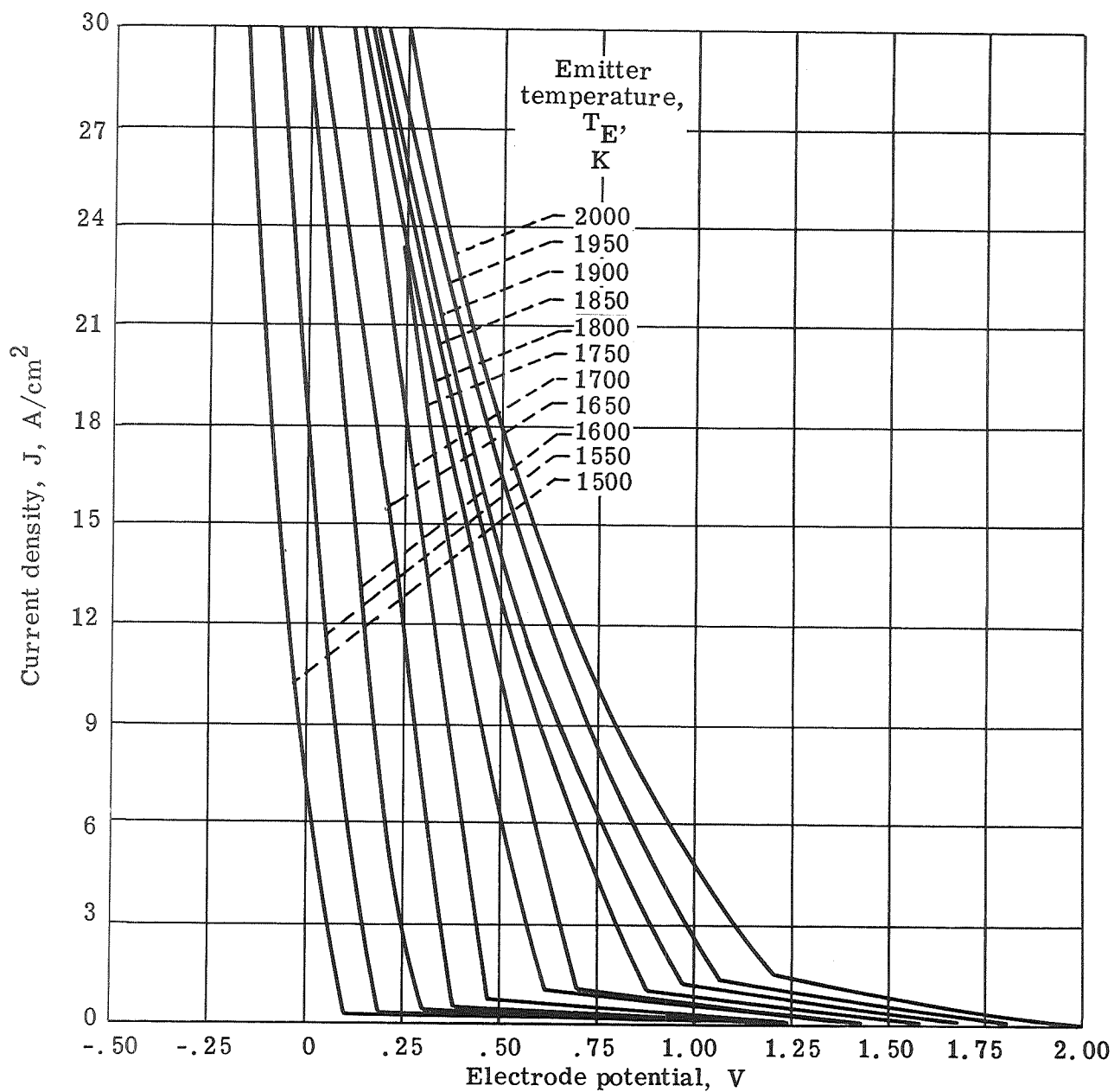


Figure 13. - Envelopes for chemically vapor-deposited tungsten, niobium planar converter at various emitter temperatures.

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